

Seventeen major sites located across the United States were once used for nuclear material production, weapon development, and weapon testing. Several of these sites are now contaminated with radionuclides, metals, or hazardous chemicals. These contaminants create a significant environmental liability that the Department of Energy (DOE) is dedicated to cleaning up.

To date, DOE has made significant progress remediating these sites by embracing a mission based on reducing risk and reducing environmental liability through fundamental scientific understanding and applied technologies. DOE intends to accelerate this progress through the integrated efforts of its Office of Science (DOE-SC), Office of Environmental Management (DOE-EM), and Richland Site Operations.



## Approach

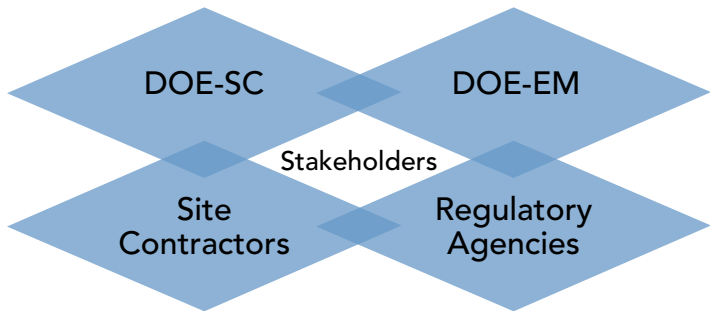
For DOE to successfully address remaining cleanup problems, it will require 1) partnering and leveraging with other relevant organizations and 2) integrating basic science and needs-driven applied research activities with DOE cleanup operations to facilitate the transition of scientific results into applied solutions.

The Initiative will provide a technical basis for quantifying, predicting, and monitoring both natural and post-remediation contaminant discharge from the vadose zone to the groundwater. It will also facilitate the development of in situ solutions that limit contaminant discharge.

The knowledge gained through the work of the Initiative will be used to transform fundamental science innovation into practical applications deployed by site contractors at Hanford and across the entire DOE complex.

The following four research areas will be targeted to achieve the goal of protecting groundwater from deep vadose zone contamination:

- Controlling processes
- Predictive modeling and data integration
- Remedial design
- Monitoring.



# Applied Field Research Initiative Deep Vadose Zone

Located on the Hanford Site in Richland, Washington, the Deep Vadose Zone Applied Field Research Initiative (DVZ AFRI) was established to protect water resources by addressing the challenge of preventing contamination in the deep vadose zone from reaching groundwater.

Led by the Pacific Northwest National Laboratory, the Initiative is a collaborative effort that leverages Department of Energy (DOE) investments in basic science and applied research and the work of site contractors to address the complex deep vadose zone contamination challenges.

## Challenge

Many vadose zone environments within the DOE complex consist of complex stratified layers of unconsolidated and water-unsaturated sediments that are, in many places, contaminated with radionuclides, metals, organics, and, in some cases, complex mixtures.

The deep vadose zone serves as both a present and potential future source of groundwater contamination. Movement of contamination from the deep vadose zone to the groundwater creates the potential for exposure and risk to receptors through contaminant uptake from water withdrawn from wells or discharge to water resources.

In addition to posing unique problems for characterization, monitoring, and remediation,

given the sheer magnitude and cost associated with addressing this first-of-a-kind technical challenge, no single organization or entity has the financial and/or technical resources available to solve the complex issues facing DOE in the deep vadose zone.

To support economically sound and sustainable solutions, the Initiative will:

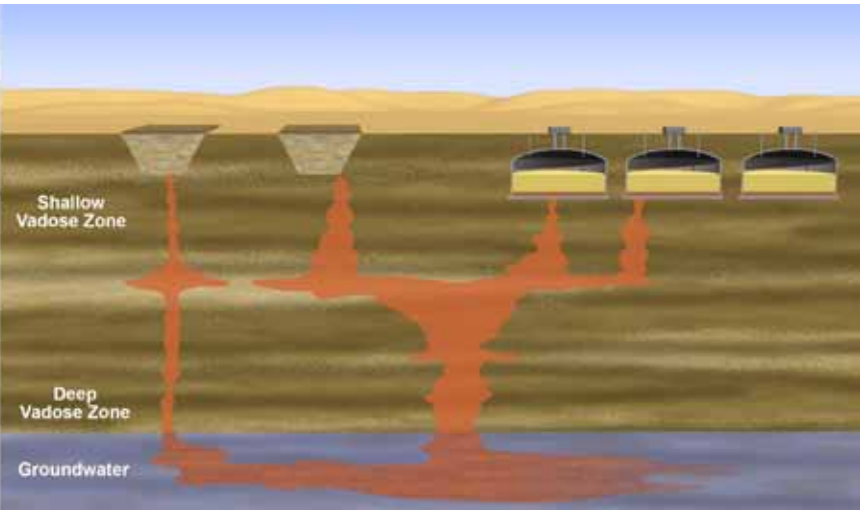
- Accelerate the development and application of essential knowledge, capabilities, and technologies
- Target investments on critical short- to long-term needs
- Confirm the understanding of contaminant behavior and remediation performance
- Enable acceleration of remedial schedules and lowering of remedial costs
- Transfer critical knowledge and remediation technologies between DOE sites.

0' to 15' below surface - limit of direct exposure pathway for human and biological activity.

~40' to 60' below surface - practical limit of excavation.

Limit of effectiveness of surface infiltration barriers.

**Deep Vadose Zone:** inventory not mitigated by surface remedy implementation that poses a continuing threat to groundwater quality.



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The Mission of the Deep Vadose Zone Applied Field Research Initiative is to protect water resources across the DOE complex over the long-term by developing effective solutions to solve DOE's most challenging deep vadose zone characterization, remediation, monitoring, and prediction challenges.

  
**Pacific Northwest**  
NATIONAL LABORATORY

 **U.S. DEPARTMENT OF**  
**ENERGY**

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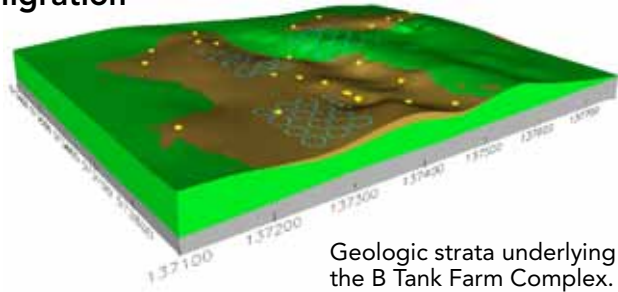


# Research and Advanced Technology Supporting Deep Vadose Zone Field Activities

## Describing Contaminant Migration

Lead Agency: DOE-RL

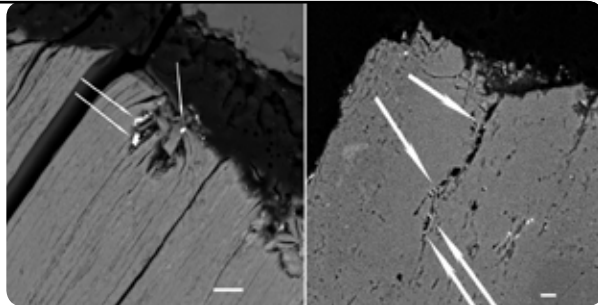
- Conceptual models developed to describe contaminant migration at key DVZ areas of interest: B Complex model complete; S Complex and T Complex models being developed



## Understanding Contaminant Behavior

Lead Agency: DOE Office of Science

- Assessed geochemical behavior of uranium beneath select tank farms
- Secondary minerals formed depends upon chemistry of released waste
- Field-scale transport models extended for use at U-8 and U-12 Cribs

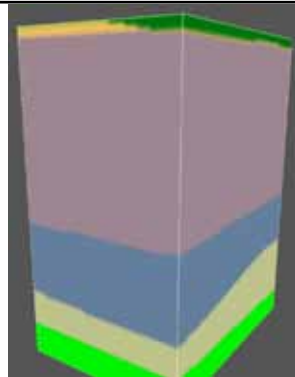


Scanning electron microscope images of uranium precipitates (small white dots) collected from DVZ sediment samples.

## Predicting Contaminant Behavior and Remediation Performance

Lead Agency: DOE-EM-32

- Developing state-of-the-art scientific tool and approach to predict contaminant movement in natural and engineered systems
- Capability will streamline transition of scientific results into applied solutions across DOE Complex

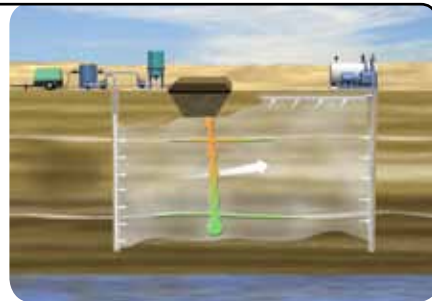


3-D view of the BC Cribs and Trenches stratigraphy developed using the model setup tool grid viewer functions of Advanced Scientific Computing for Environmental Management (ASCEM).

## Delivering Treatment

Lead Agency: DOE-EM-32

- Remedial amendment emplacement in vadose zone environments
- Overcomes heterogeneous distribution
- Penetrates low-permeability, contaminant source zones



Use of Foam Delivery Technology in the subsurface (not to scale).

Surface

Near-Surface

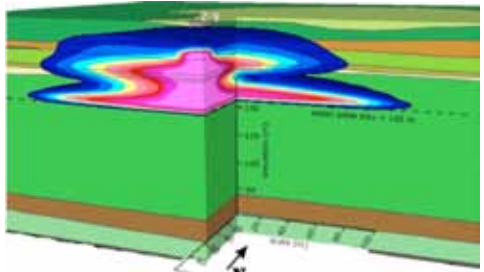
Vadose Zone

Groundwater

## Developing Defensible Endpoints for Remedial Actions

Lead Agency: DOE-EM-32

- Soil Vapor Extraction (SVE) is baseline remedy for volatile organics
- Developing defensible endpoints for SVE and alternatives to protect groundwater

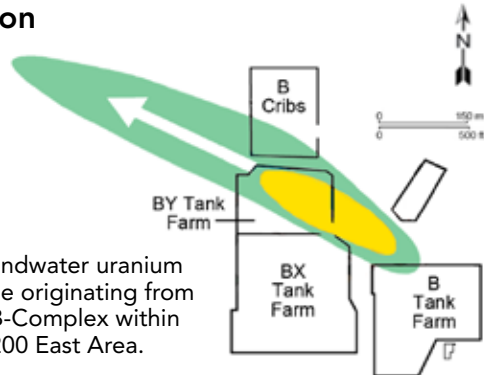


Simulated CCl<sub>4</sub> vapor distribution and concentration in the DVZ when vapor extraction was initiated.

## Determining Sources of Contamination

Lead Agency: DOE Basic Energy Sciences

- Uranium isotopic ratios provide insight into contaminant origin
- LBNL instruments pinpointed origin of an emerging uranium plume in Hanford groundwater



Groundwater uranium plume originating from the B-Complex within the 200 East Area.

## Controlling Flux

Lead Agency: DOE-EM

- Surface barriers reduce shallow contaminant movement by decreasing water infiltration
- Understanding barrier performance key to verifying their value in remediation

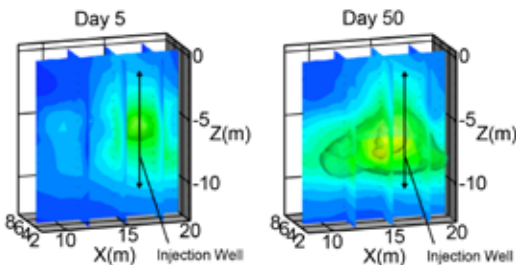


Aerial Photograph of the Hanford Surface Engineered Barrier.

## Providing Scientific and Technical Defense for Remedial Actions

Lead Agency: DOE-RL

- Treatability testing underway with field tests planned for desiccation, uranium sequestration, and pore water extraction
- Applied research supporting tests through such activities as:
  - ▶ Laboratory and modeling input to field test designs and data interpretation
  - ▶ Evaluation and selection of reactive gases for U/Tc sequestration
  - ▶ Advanced geophysical modeling of remediation processes
  - ▶ Evaluation of potential DVZ solutions



Example of tomographic imaging that can track remedial progress in the subsurface.

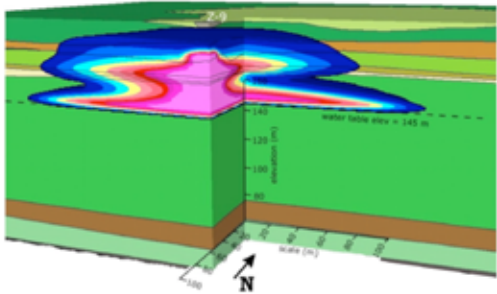


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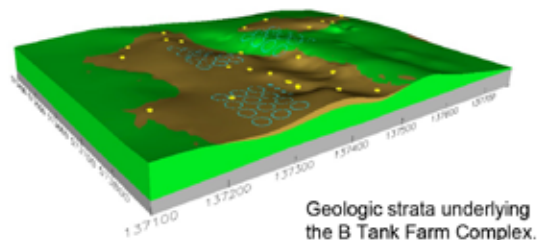


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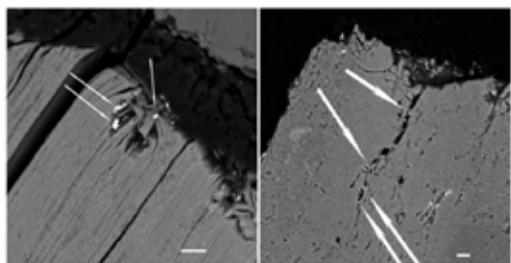


Geologic strata underlying the B Tank Farm Complex.

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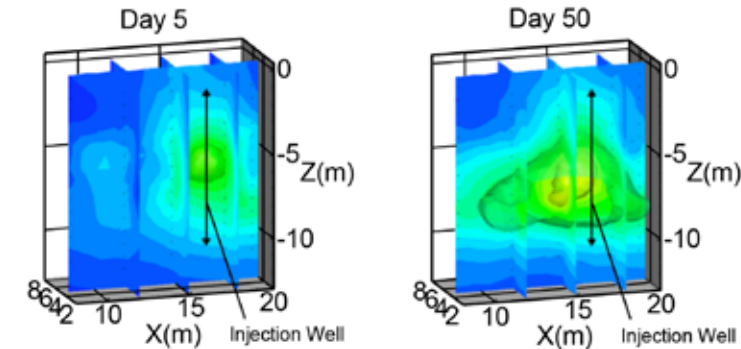


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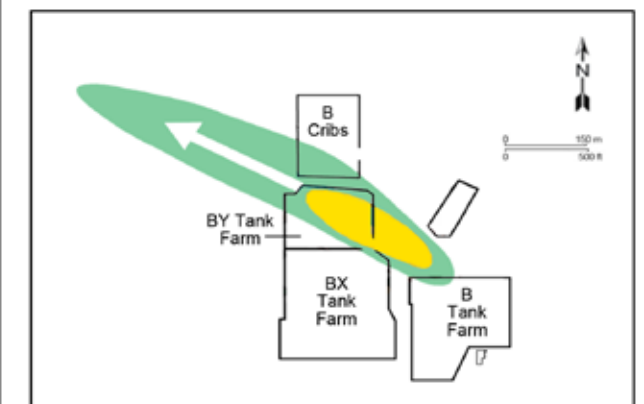


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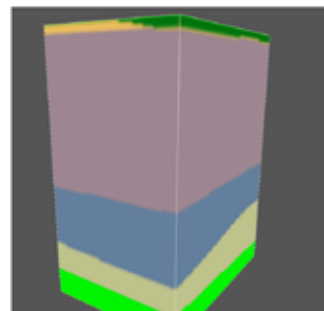


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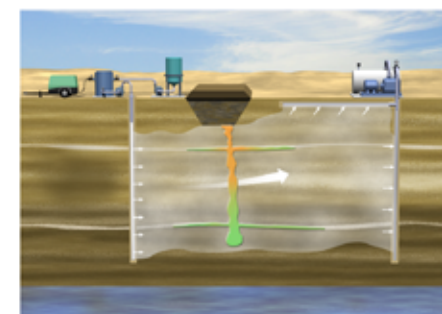


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Capability applies across the Inner Area